a screw acts against a long pliable spring, to which there are serious objections. In the arrangement shown in figs. 8 and 9 the advantage of having all backlash taken up by a spring is retained, while a very stiff spring can be employed. In figs. 8 and 9, *a* is

Fig. 8.

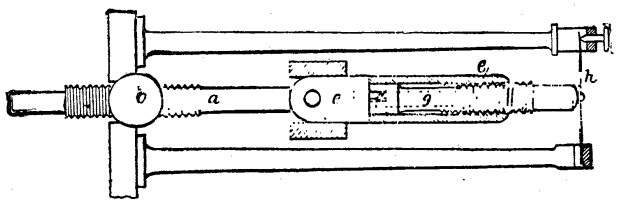
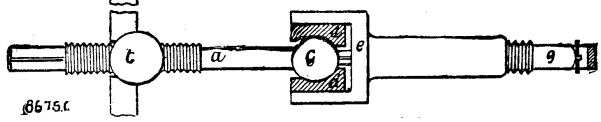


Fig. 9.



the screw by which the adjustment is made, this screw working through a nut *b*, and having a spherical end *c* bearing in the crosshead *d*. Thus, as the screw is turned the distance between the nut *b* and crosshead *d* is varied. At *h* is a short stiff spring, which by means of the screw *g* and sleeve *e* exerts a pressure on the crosshead *d*. At *f* is a square prolongation of the screw *a*, which enters a correspondingly squared hole in the screw *g* so that the latter turns with *a*. But whereas the screw *a* has a right-hand thread, that of the screw *g* is left-handed, so that every increase of distance between the nut *b* and crosshead *d* is accompanied by an equal decrease in the length of the combination *g e*, and thus the pressure exerted by the spring remains constant, whatever may be the position of the crosshead *d*.

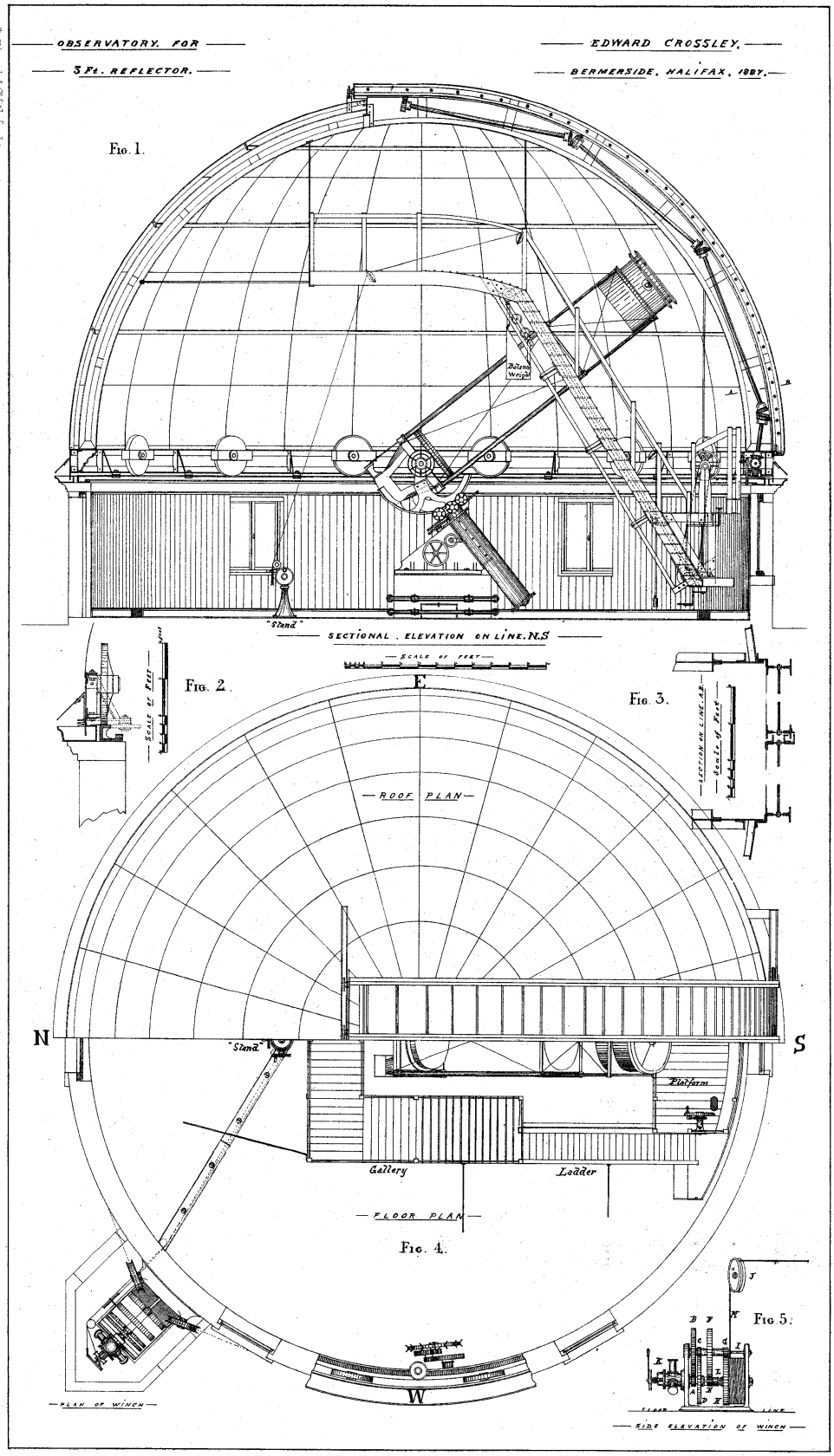
Description of a New Observatory for a 3-foot Reflector.

By Edward Crossley.

On the removal of Mr. Common's 3-foot reflector from Ealing the ingenious wooden house, or observatory, designed by Mr. Common was also re-erected at Halifax. The situation at Halifax being much more exposed than that at Ealing, it was soon found very desirable to put up a dome so as more effectively to protect both the instrument and the observer. The present dome was completed in 1887. It is constructed in a similar manner to the excellent dome by Messrs. Cooke of York, at the Greenwich Observatory, except so far as the covering and the shutters and some of the minor details are concerned.

The accompanying plan and section, with the following explanation, will perhaps make the construction plain.

The building is circular, the same diameter as the dome—38 ft. 9 in. outside and 36 ft. 3 in. inside. The walls are stone outside and brick inside. The circular wall is 1 ft. 3 in. thick, 7 ft. 4 in. high above the floor, and finishing with an ashlar



course carefully levelled to receive the rail. A north doorway and five windows give access and ventilation. A small room at the N.W. corner, with a flat roof, contains an hydraulic winch for moving the dome.

Fig. 2 shows the top of the wall in section on a larger scale.

The rail is of cast-iron, in 24 segments, planed top and bottom, bolted together and to the masonwork, and carrying a toothed rack all round on the inner side containing 1,392 teeth. Outside is the rain-trough. The foundation ring of the dome is made of $\frac{1}{4}$-inch boiler-plate 21 inches deep, with 4-inch angle-iron top and bottom. To this ring are attached the cast-iron frames in which the 14 large wheels rotate that carry the dome, and also the intermediate wheels that keep the dome in its place horizontally. Outside the ring is a snow-guard, set off from the dome to allow the rainwater to enter the trough. There is also a series of double forks, one of which is shown in fig. 2. These forks carry the two wire ropes, $\frac{3}{8}$-inch in diameter, by which the dome is moved round, so that they do not touch the dome and catch the rainwater from it. To make the dome weatherproof, there is placed immediately above the trough and between the ring and the rail a flat strip of galvanised iron attached to the ring, and from the rail a similar strip of felt cloth covering the iron plate. Two stout parallel girders 6 feet apart run from one side of the dome to the other to support the shutters, and form the opening of the dome. These girders are made of $\frac{1}{4}$-inch boiler-plate 11 inches deep, with 3-inch angle-iron both sides, top and bottom, up to the north side of the opening. Along the opening the girders are 17 inches deep, as shown in section, fig. 3, and extend beyond the shell of the dome to form the sides of the opening. These girders are attached to the ring of the dome by angle blocks, as shown in fig. 1 to the north. The foundation ring is divided into 24 equal parts. From 23 of these rise 2-inch T-section wrought-iron ribs bound together by three $1\frac{3}{4}$-inch angle-iron rings, as shown in fig. 1. The 206 sheets of galvanised iron $\frac{1}{12}$-inch thick which form the covering of the dome are riveted to the ribs as well as to each other with 11,000 rivets. The two shutters are parallel, and open horizontally, and are carried at each end by pullies on rails.

Each shutter is opened by a system of shafting, as shown in fig. 1. The shafting is carried up the sides of the opening on each girder, and the lengths are connected by bevil-wheels. Four cogwheels on the shafting work into four racks upon the shutter. The two systems of shafting are connected together at the bottom of the opening by a cross-shaft and bevil-wheels. A worm-wheel upon the cross-shaft, with worm and handle, as shown in fig. 1, enable both shutters to be opened and closed simultaneously in one minute each way. The shutters are shown in section, fig. 3, both closed. The sections are broken to save room. A trough is formed by angle-iron in one of the shutter ribs to catch any rain that may drive in. This trough is partly

packed with tarred gaskin to make a tight joint with the other shutter when closed. In addition to the outer shutters a light shutter 9 feet by 6 feet is carried between the girders at the zenith and rolled back to north when not required. This shutter gives additional protection to the delicate parts of the instrument, and also shuts out the zenith when not required. It is omitted in the drawing, to avoid complication. The rods which connect the shutter-girders form steps for reaching the top of the dome (see fig. 4).

To enable the observatory to be worked with ease by one observer, an hydraulic winch is placed outside the main wall at the N.W. corner. Figs. 4 and 5 show this in plan and elevation. The winch is constructed as follows. Upon a cast-iron bed plate at each end are bolted two vertical frames. These frames carry two parallel shafts, one over the other. The upper one is fixed, forming a stay to the frames. The lower one is driven by the 3-cylinder water-engine *K*, with cylinders 3 inches diameter and 5 inches stroke, fig. 5. The gearing is in four couples, *A*—*B*, *C*—*D*, *E*—*F*, *G*—*H*, numbered respectively 23—109, 23—109, 16—77, 16—77. *A* is the only wheel keyed fast to its shaft. *B*, *C* and *F*, *G* are pairs, moving freely round together on the upper shaft. The pinion *E* slides on the lower shaft, and can be coupled either to wheel *D* or to a block, *L*, which is keyed fast to the shaft, or remain idle between the two. When the pinion *E* is coupled to *D* then all four sets of wheels are at work, and $5\frac{1}{2}$ revolutions of the water-engine will turn the dome round once in 24 hours. When the pinion *E* is coupled to the block *L* only *E*—*F*, *G*—*H* are at work; *A*—*B*, *C*—*D* run idle, and 72 revolutions of the engine will turn the dome round once in 5 minutes. It is obvious that any intermediate speed can be obtained. The wire ropes are fastened at each end upon the drum and dome respectively. As one rope winds on to the drum the other winds off. The pulley *J* is out of place in the drawing. The rope *M* should come to the middle of the drum. Pullies are placed at *M* to take up any slack there may be in the ropes, but are not shown, to avoid complication.

The valve of the water-engine is connected by wire cords under the floor with the stand on the north side of the telescope. The coupling lever of the pinion *E* is also connected in the same manner, so that the speed and direction of the rotation of the dome can be controlled from the floor of the observatory.

The arrangements for supporting the observer at the eye-piece of the reflector are as follows. A substantial wooden gallery, shaped like the letter U, with railings inside and out, is suspended from the top of the dome and stayed laterally with iron rods, as shown in figs. 1 and 4. Two stout ladders descend from the south ends of the U-gallery to within 15 inches of the floor of the observatory. The lower ends of the ladders are firmly connected together, and also suspended from the dome.

Each ladder has an outside railing. Between the ladders is placed the movable platform, with a triangular frame at each end, carrying rollers resting upon cast-iron rails on the inner side of each ladder, and supported by two balance weights, one of which is shown in fig. 1. On the under-side of each rail is a rack. A shaft with pinions at each end gearing into the racks is carried by bearings under the platform. This shaft is turned by an endless chain and handle upon the platform, as shown in figs. 1 and 4. A safety-catch fitting into a notched wheel upon the shaft prevents the platform from falling with two or more persons upon it. The catch is raised by the left foot upon the plate, shown in fig. 4 close to the hand-wheel. The mechanism is indicated in fig. 1. The platform is balanced to carry one person, and is easily raised and lowered.

The mechanism for opening the shutters is worked from the platform. Two light cords are carried up from the stand over pulley-blocks on the west side of the gallery and platform, so that the observer by pulling the cords can control the winch and move the dome without leaving the eye-end of the telescope in whatever position it may be. Should the water-supply be cut off from any cause, the winch drum I is set free by sliding the pinion G out of gear with H, and the dome is moved by the hand-rope gearing shown due west, fig. 4. An endless rope passes over the large wheel, and the cog-wheels numbered 16–72, 24–84, 17, are thrown, with No. 17, into gear with the rack upon the wall of the observatory. The stud brackets (not shown, to avoid complication) carrying the hand-gear wheels are attached to the foundation ring of the dome. By this means the dome can be easily moved through 90° by one person in 5 minutes. The rack and hand-gear might be dispensed with provided a handle within the observatory was connected by a shaft and pinion with the gearing of the winch outside.

In order to preserve the telescope from damp, hot-water pipes are brought in at the east side of the observatory under the floor and carried round the foundation of instrument, as shown in fig. 1. The circulation can be cut off at once, and the warm water in the pipes replaced by cold.

The total area for ventilation when all is open is equal to $\frac{1}{9}$th the area of the dome. The water-engine can be utilised to facilitate the ventilation of the observatory, if necessary, by driving a small fan.

The weight of the dome is about 14 tons. The weight of the platform, steps, and gallery (about $1\frac{1}{2}$ ton) is additional to this. 7 lbs. on the endless rope of the hand-gear will move the dome.

The construction and erection of the dome has been ably carried out by Messrs. Clapham Bros., of Keighley, Yorkshire, especially as it is the first astronomical dome which they have constructed.

I hope in a future paper to give some account of the telescope and its work.
